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**Sun et al.**

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(54) **OLED PANEL HAVING AUXILIARY CATHODE**

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(Continued)

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(56) **References Cited**

U.S. PATENT DOCUMENTS

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7,619,359 B2\* 11/2009 Kim ..... B82Y 20/00 313/504  
7,621,793 B2\* 11/2009 Makiura ..... H01L 51/5088 313/504

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(Continued)

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FOREIGN PATENT DOCUMENTS

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CN 101097944 A 1/2008  
CN 104637956 A 5/2015

(Continued)

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OTHER PUBLICATIONS

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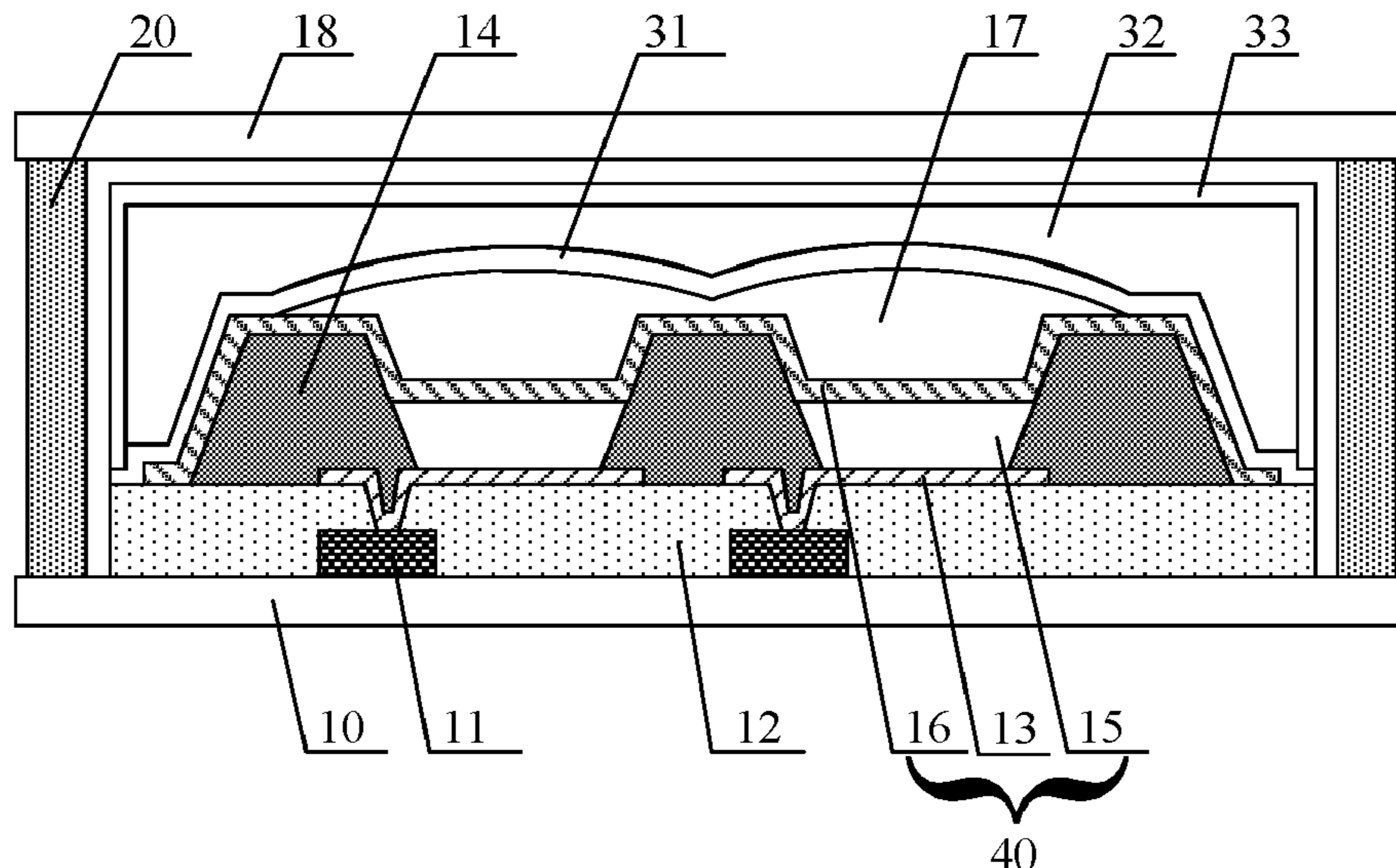
(57) **ABSTRACT**

An OLED panel and a manufacturing method thereof are provided. The panel includes a substrate, a plurality of OLED devices disposed on the substrate and an auxiliary cathode. The OLED devices include a cathode and have light emitting areas respectively. The auxiliary cathode is disposed on the cathode of the OLED devices in electrical contact with the cathode and the auxiliary cathode is at least partially located in the light emitting areas of the OLED devices. A material of the auxiliary cathode is a transparent conductive material.

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(56) **References Cited**

U.S. PATENT DOCUMENTS

10,021,741 B2 \* 7/2018 Lee ..... C23C 16/401  
10,181,582 B2 \* 1/2019 Matsusue ..... H01L 51/5092  
10,193,100 B2 1/2019 Qi et al.  
2005/0248270 A1 \* 11/2005 Ghosh ..... H01L 51/524  
313/512  
2008/0001537 A1 1/2008 Chen et al.

FOREIGN PATENT DOCUMENTS

CN 105428548 A 3/2016  
CN 205092271 U 3/2016

\* cited by examiner

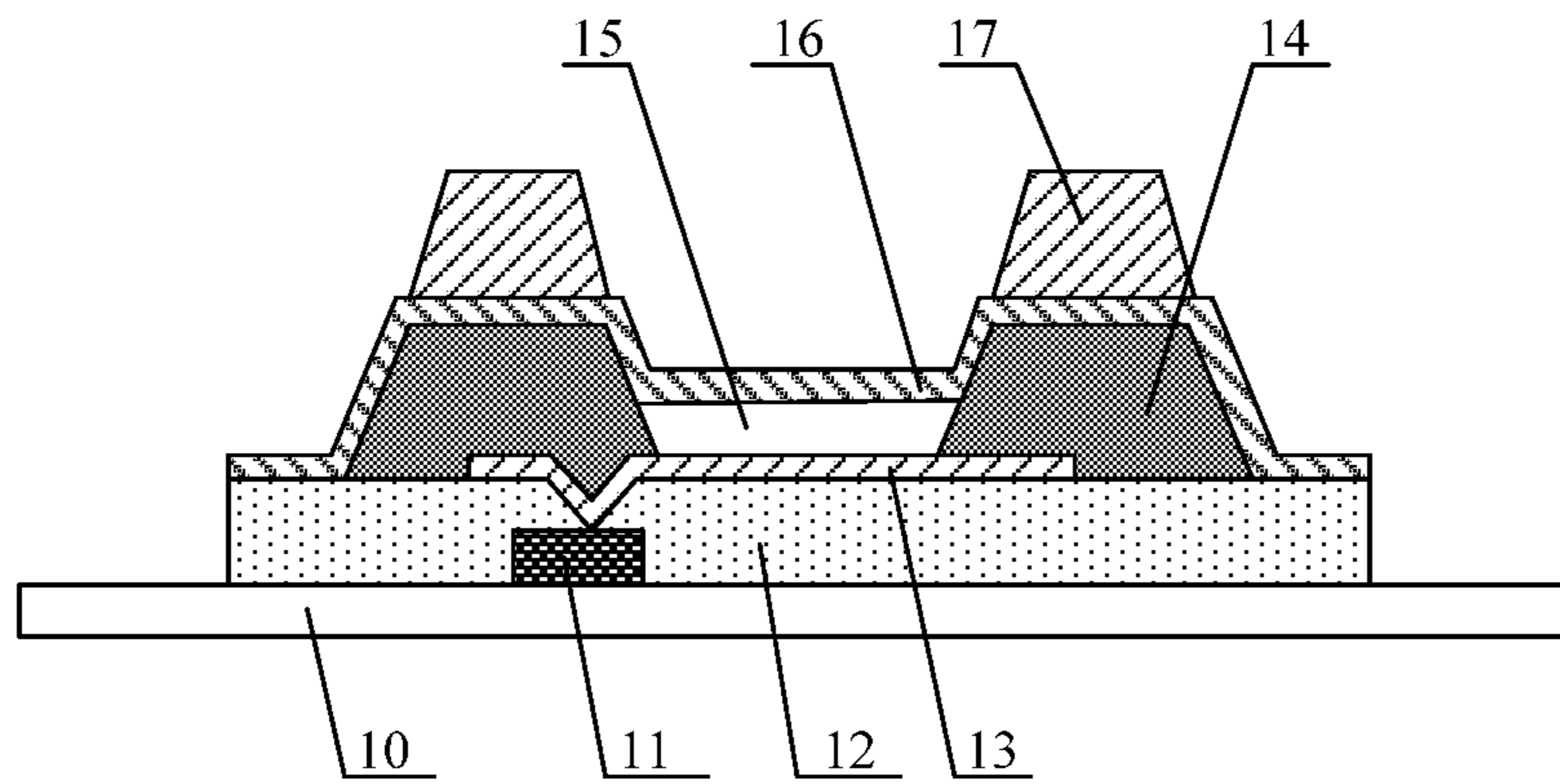


FIG. 1A

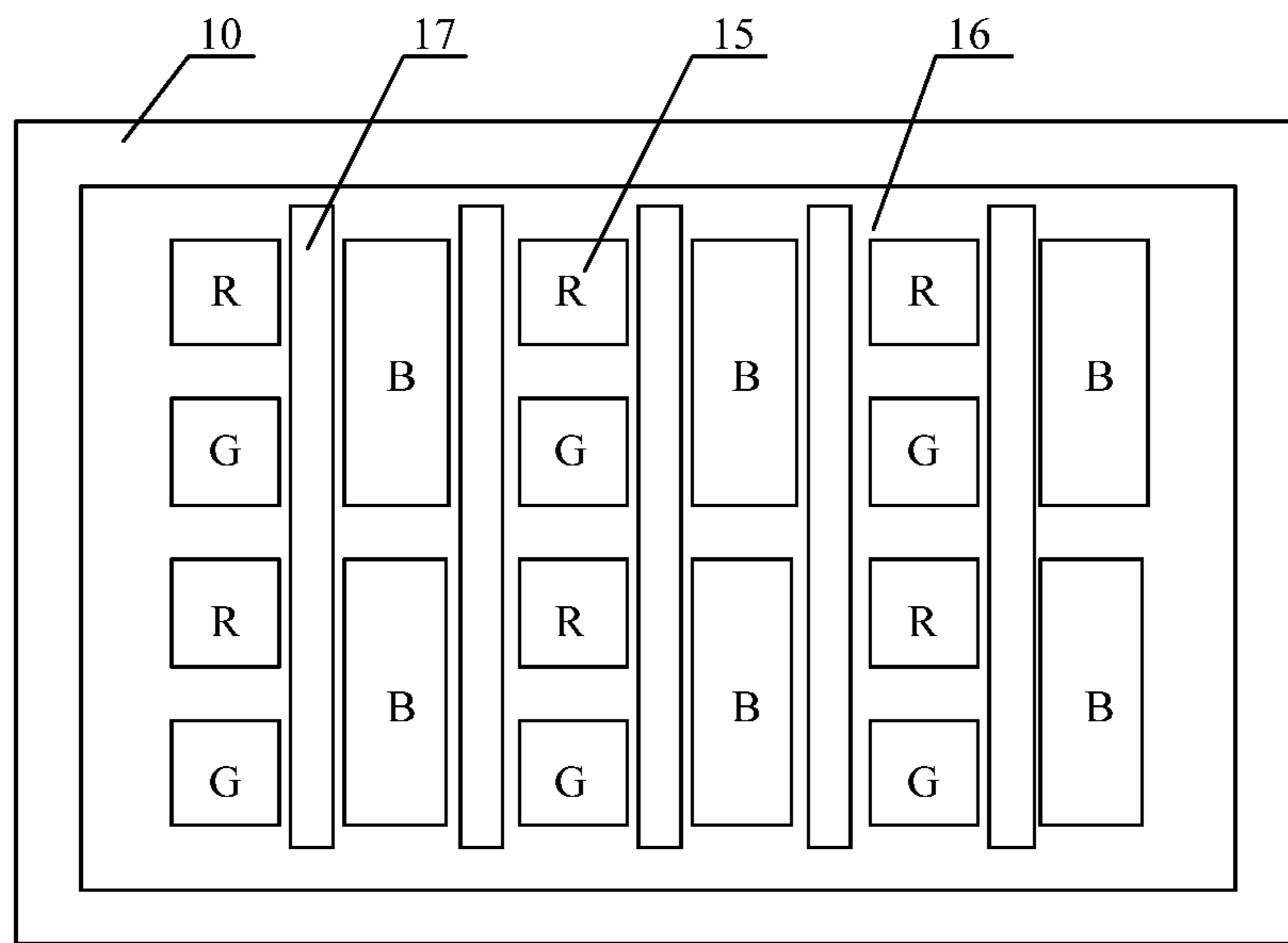


FIG. 1B

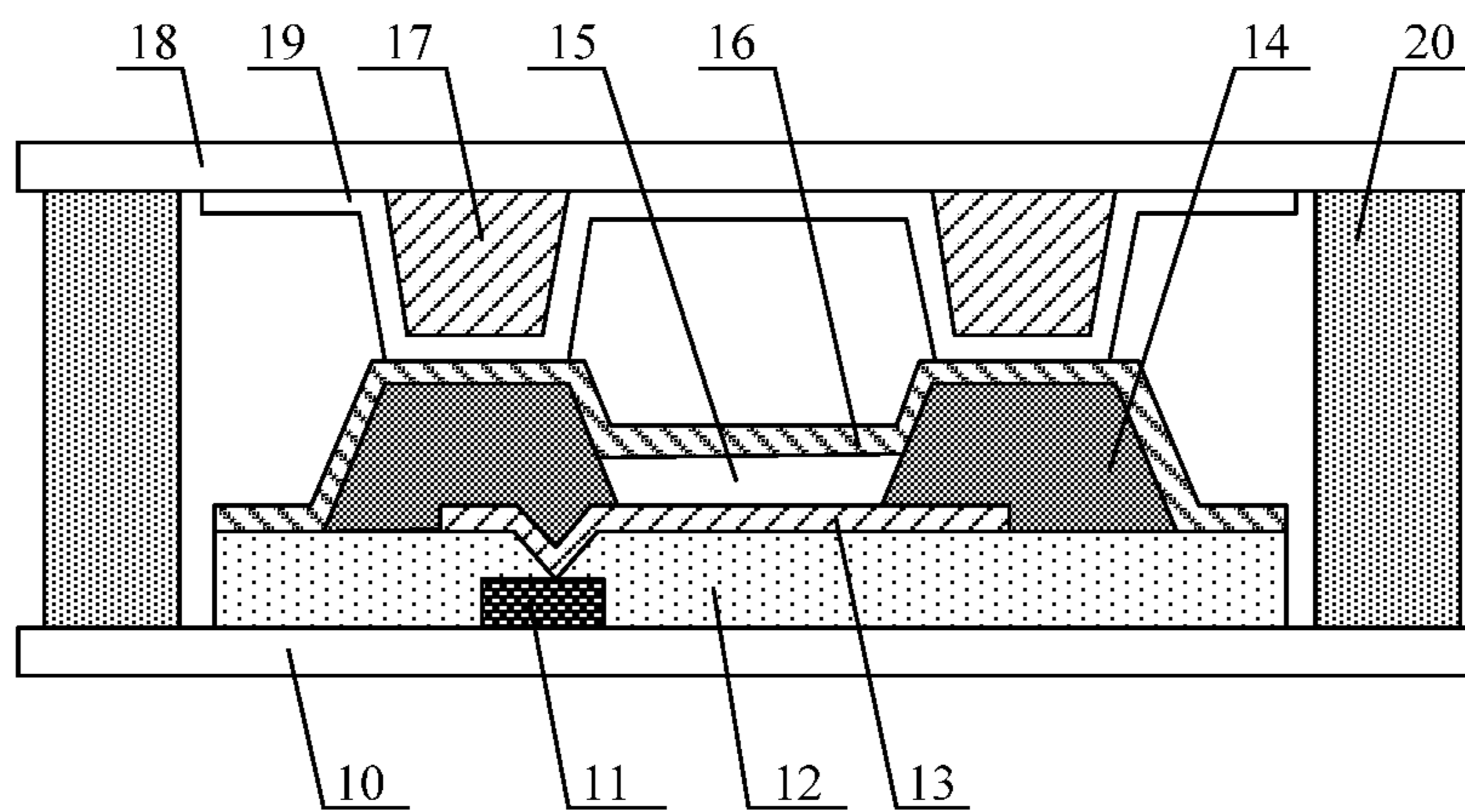


FIG. 2

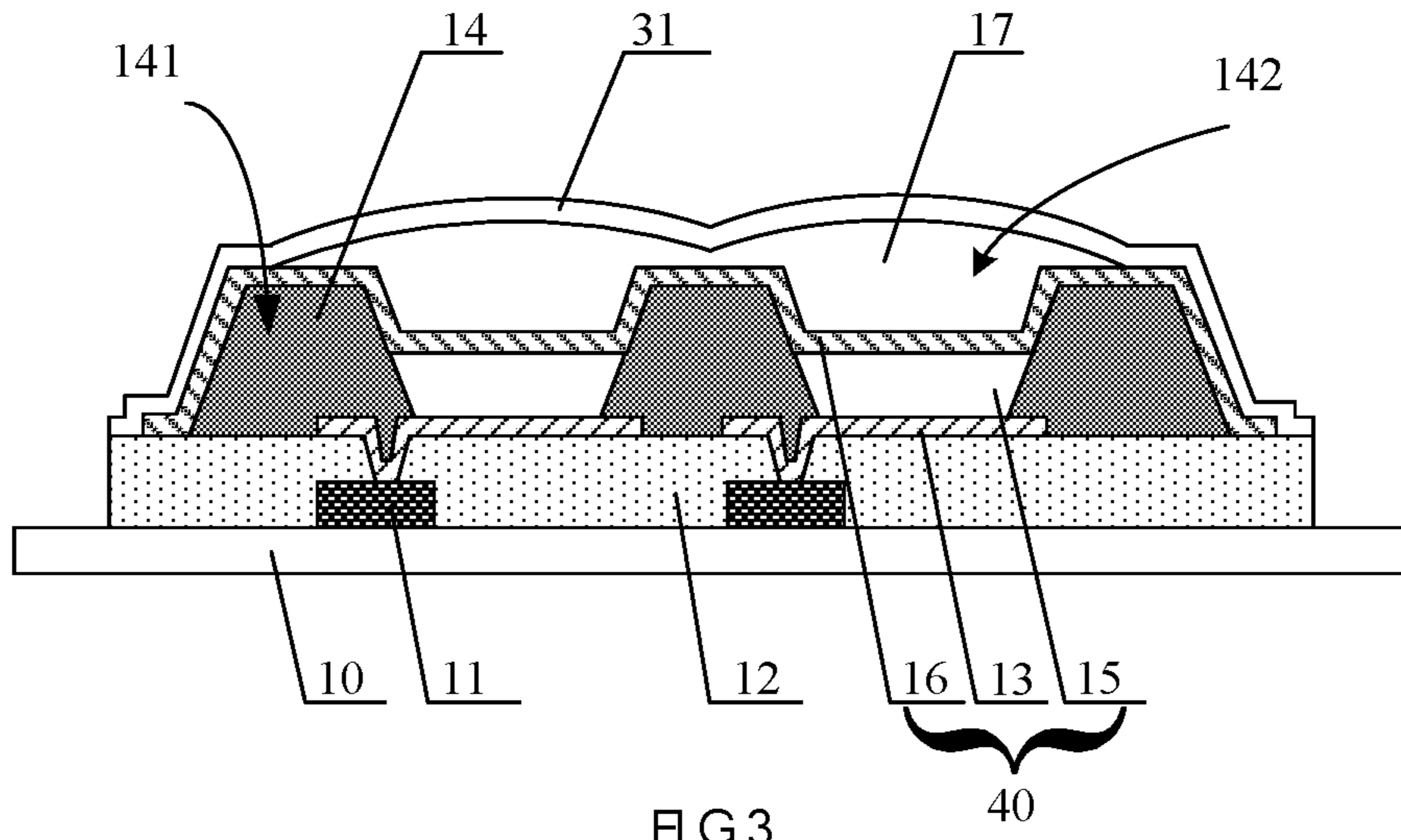


FIG 3

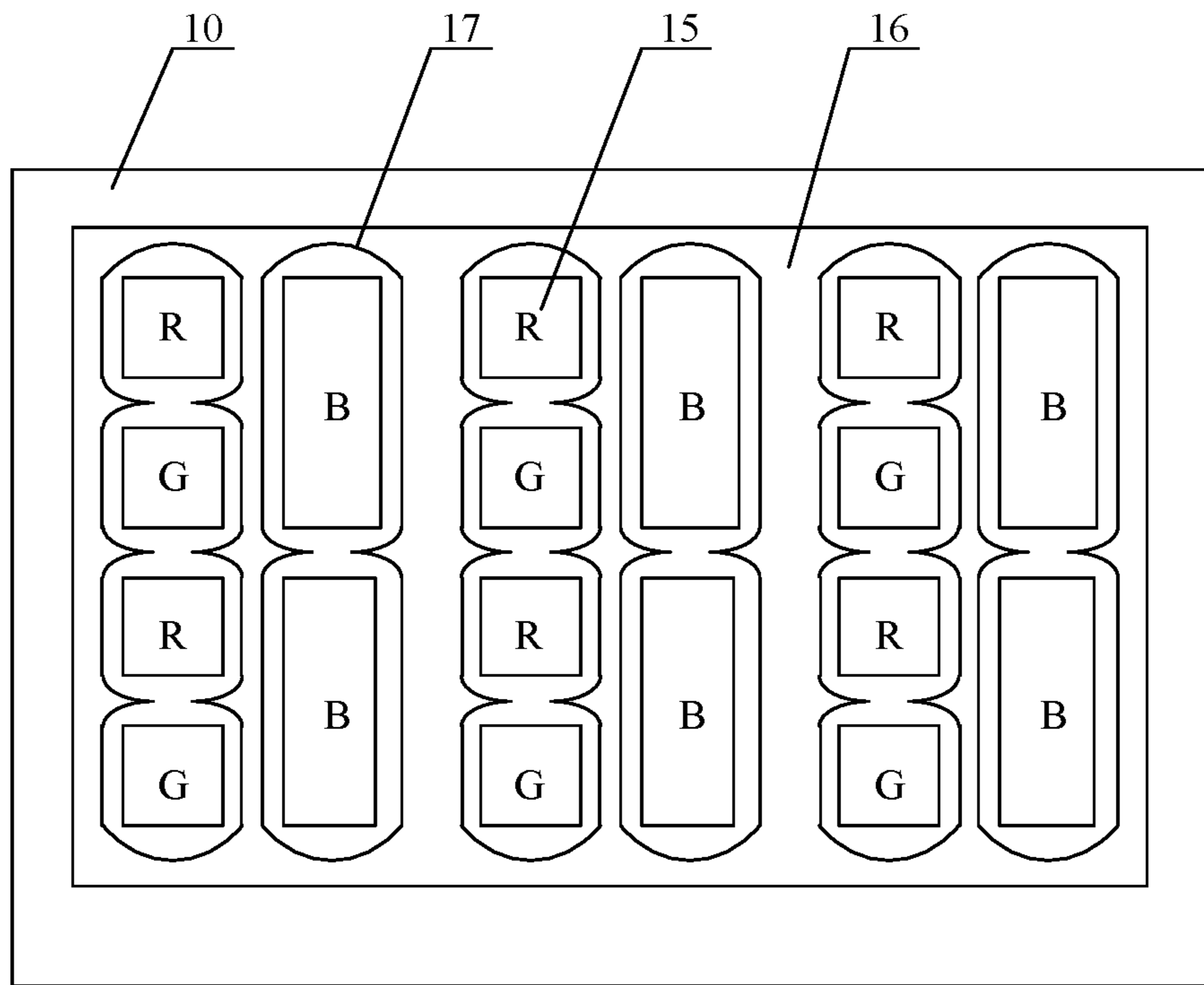
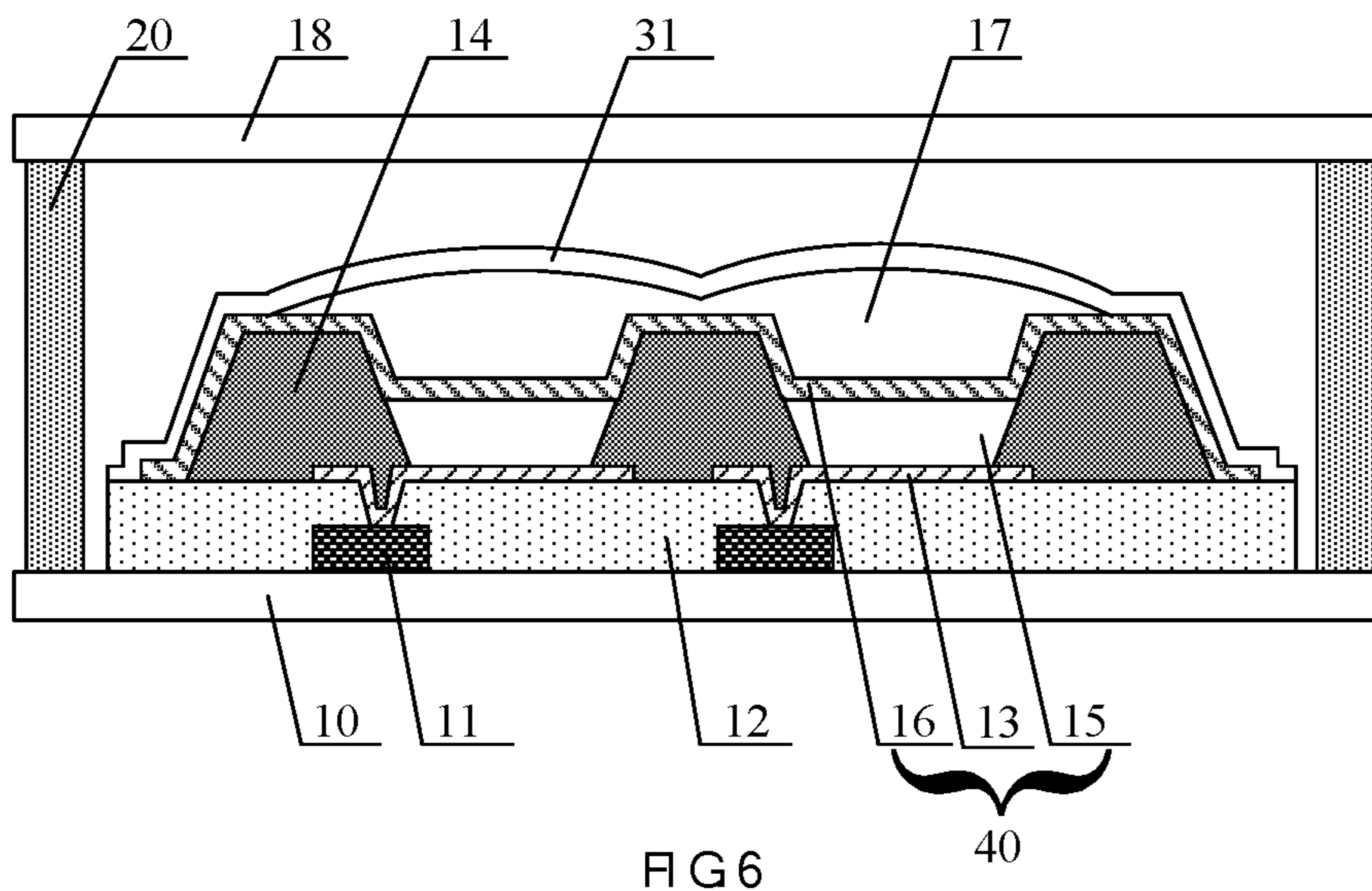
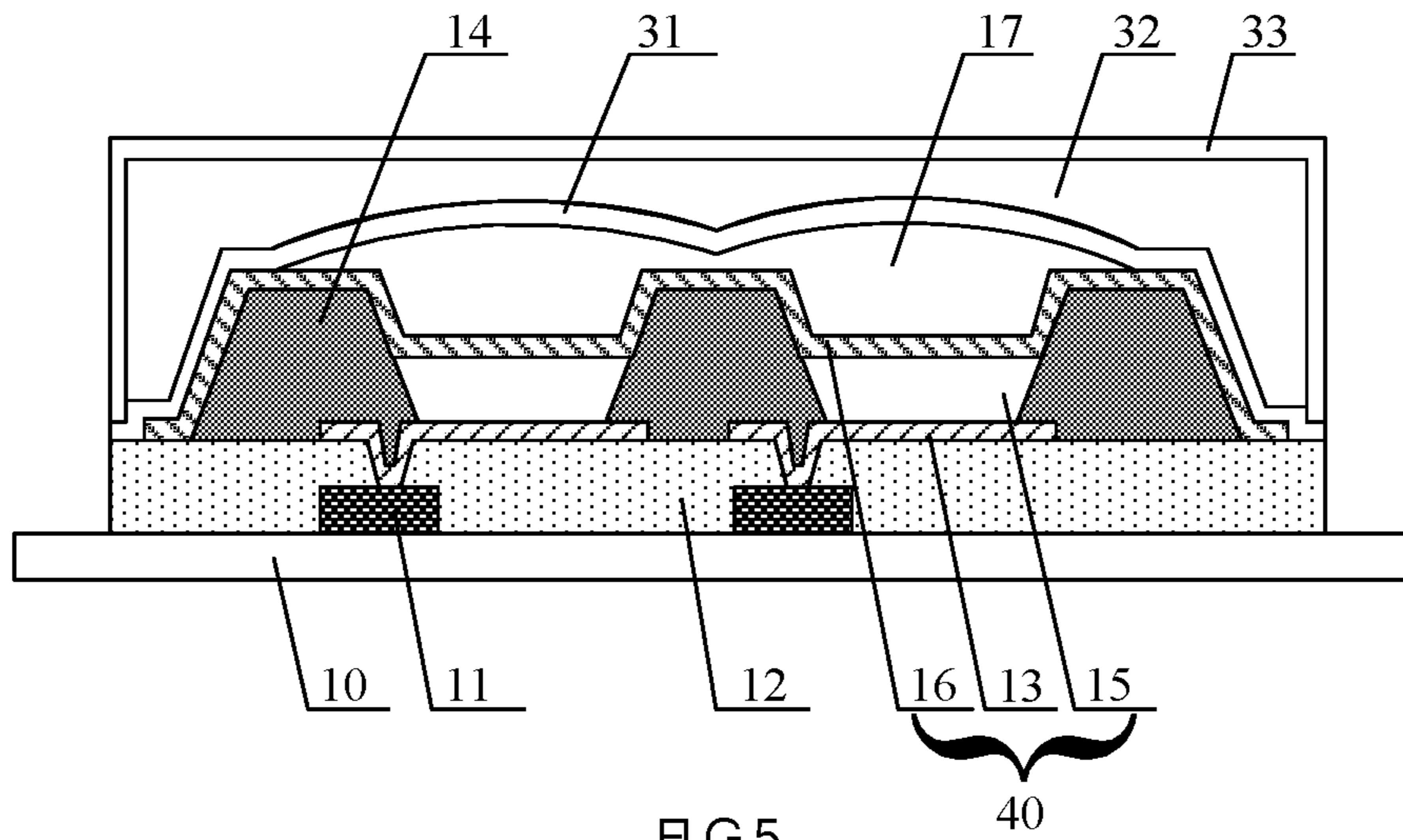


FIG 4



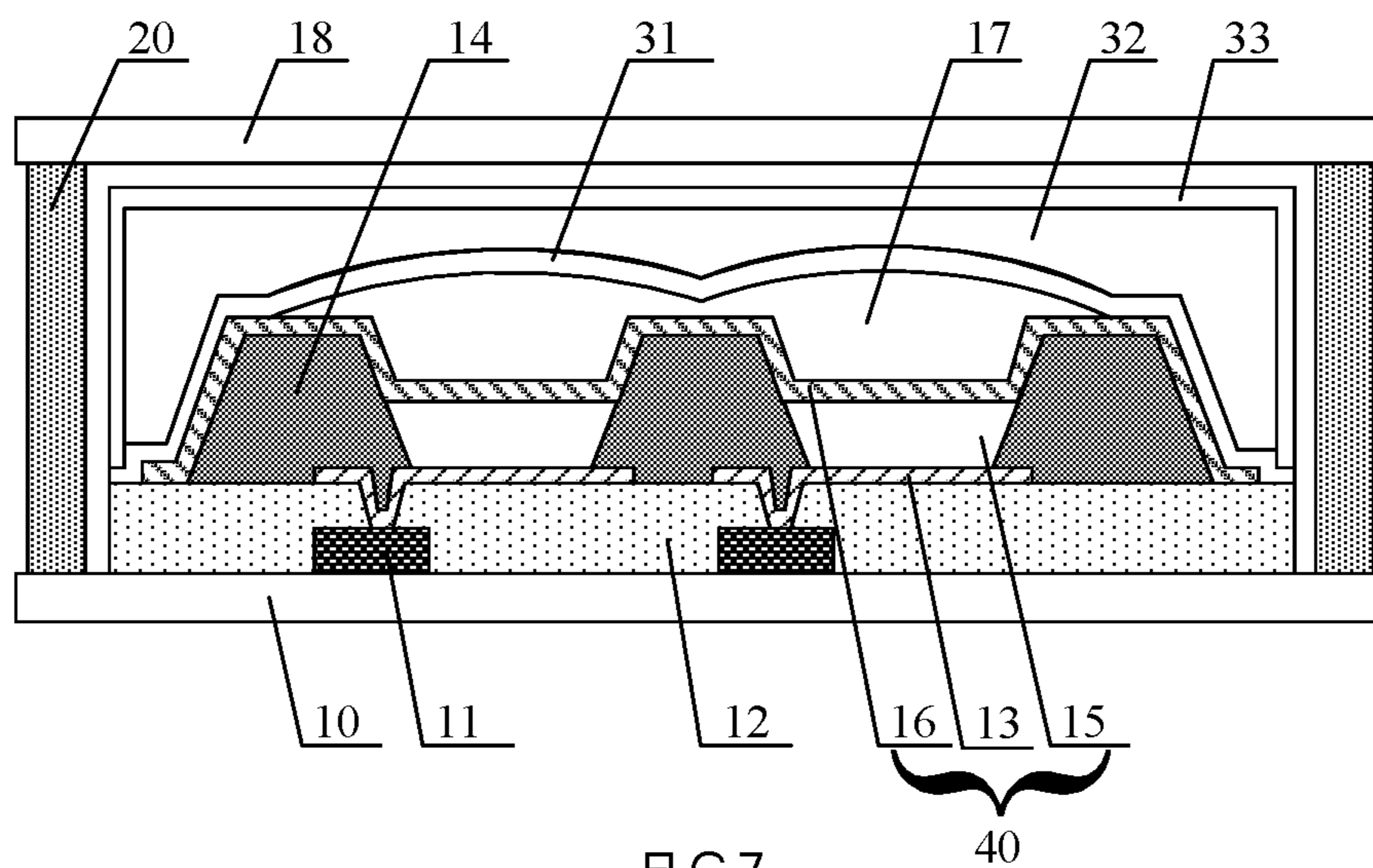


FIG 7

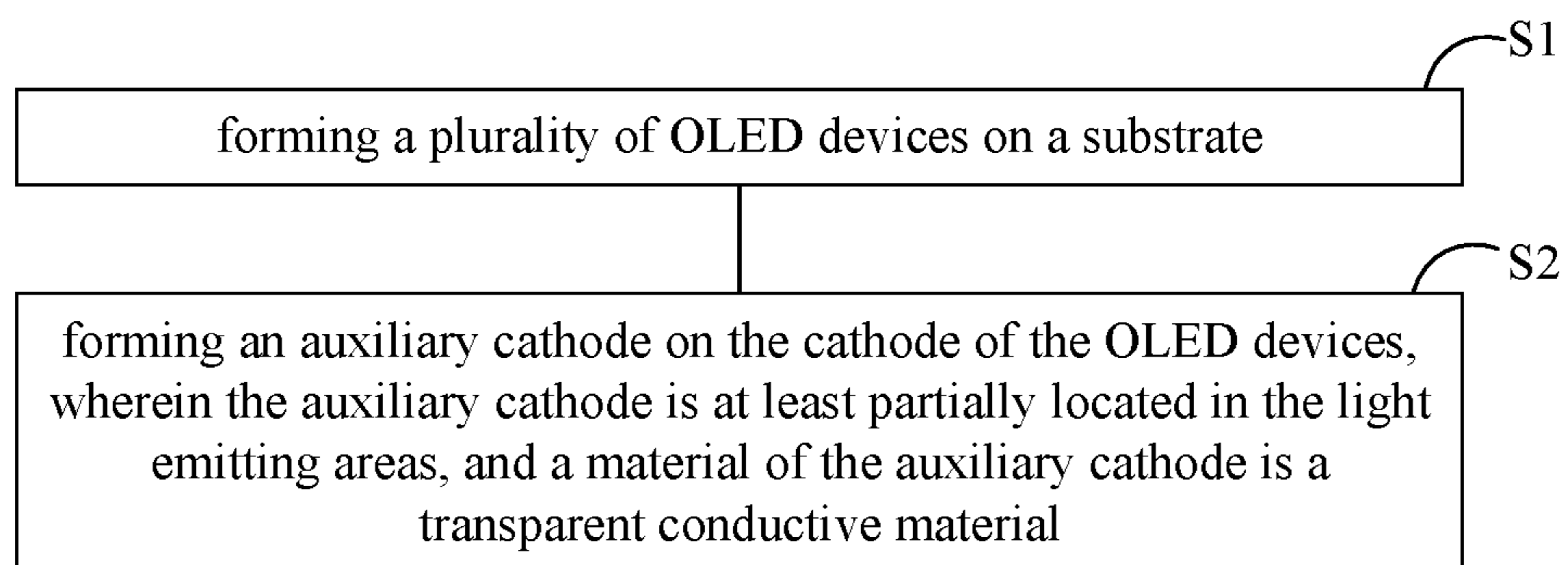


FIG 8



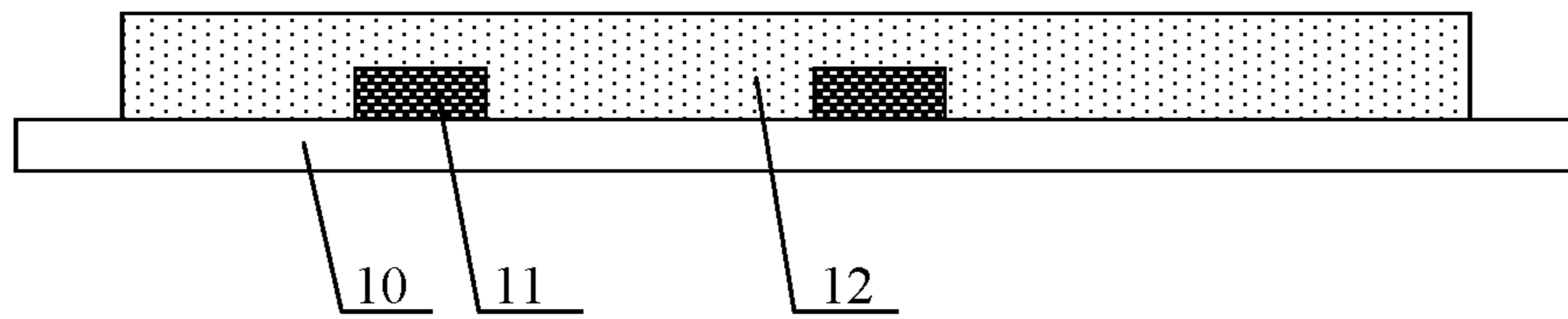


FIG 9

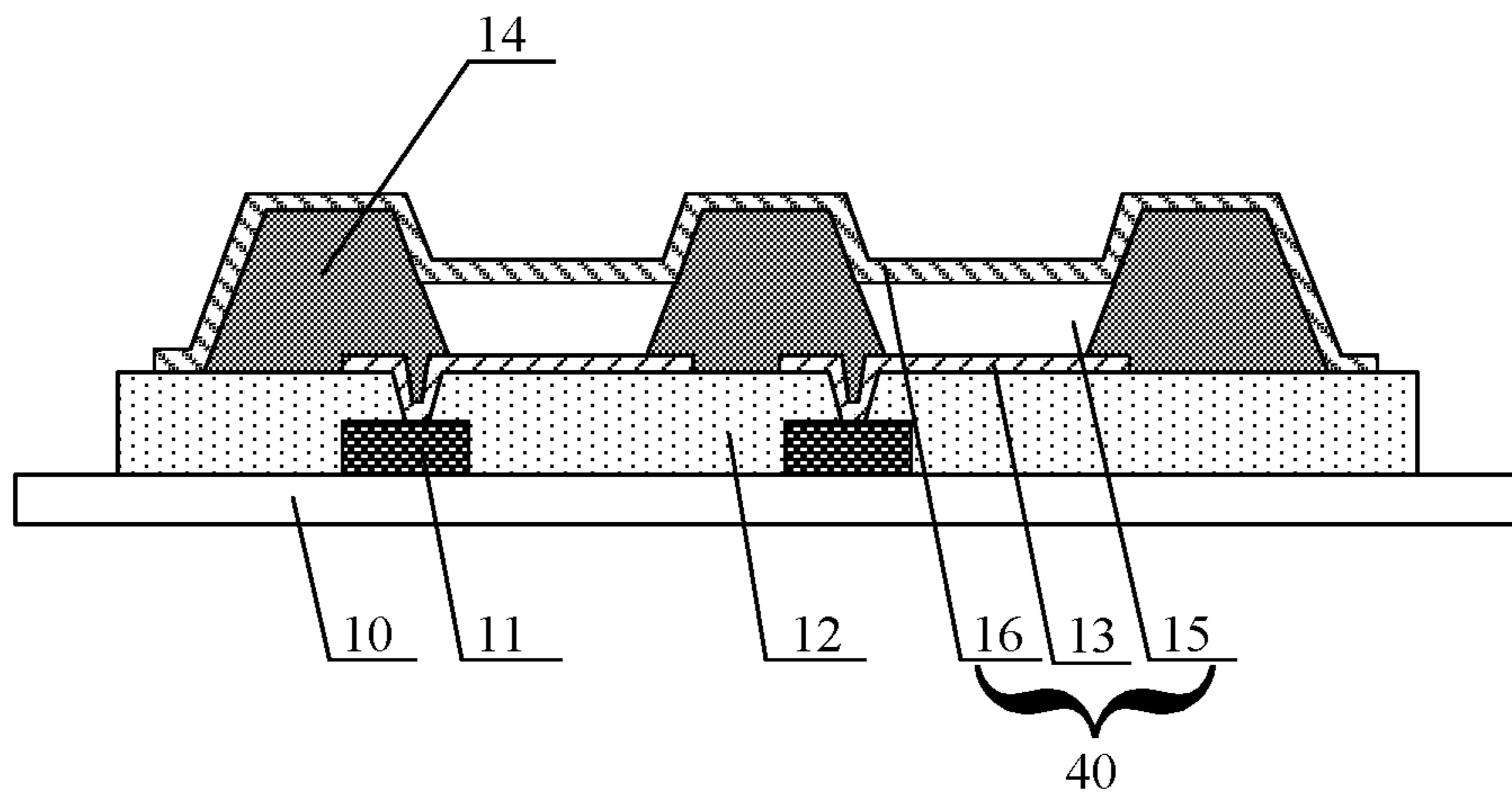


FIG 10

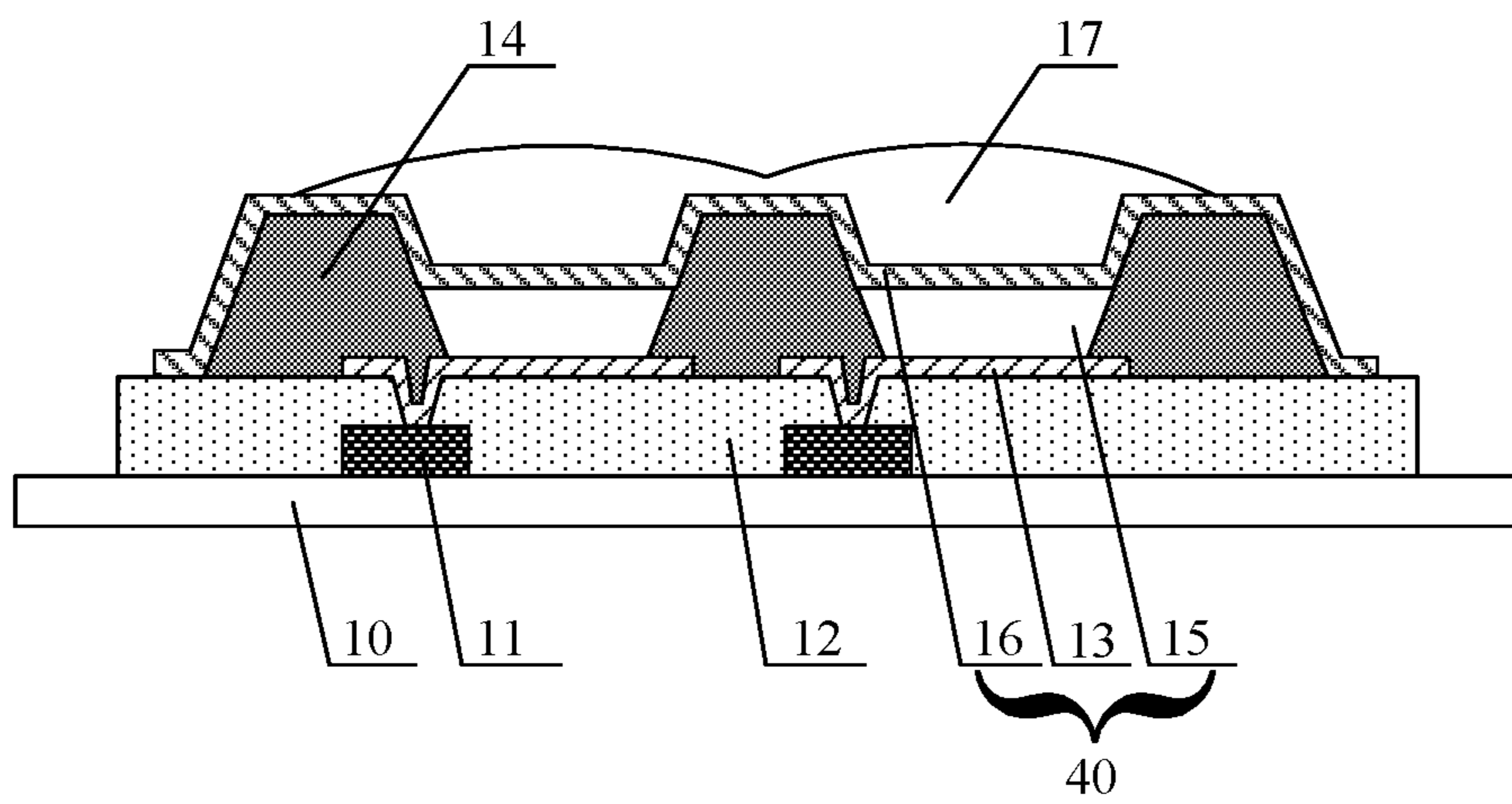


FIG 11

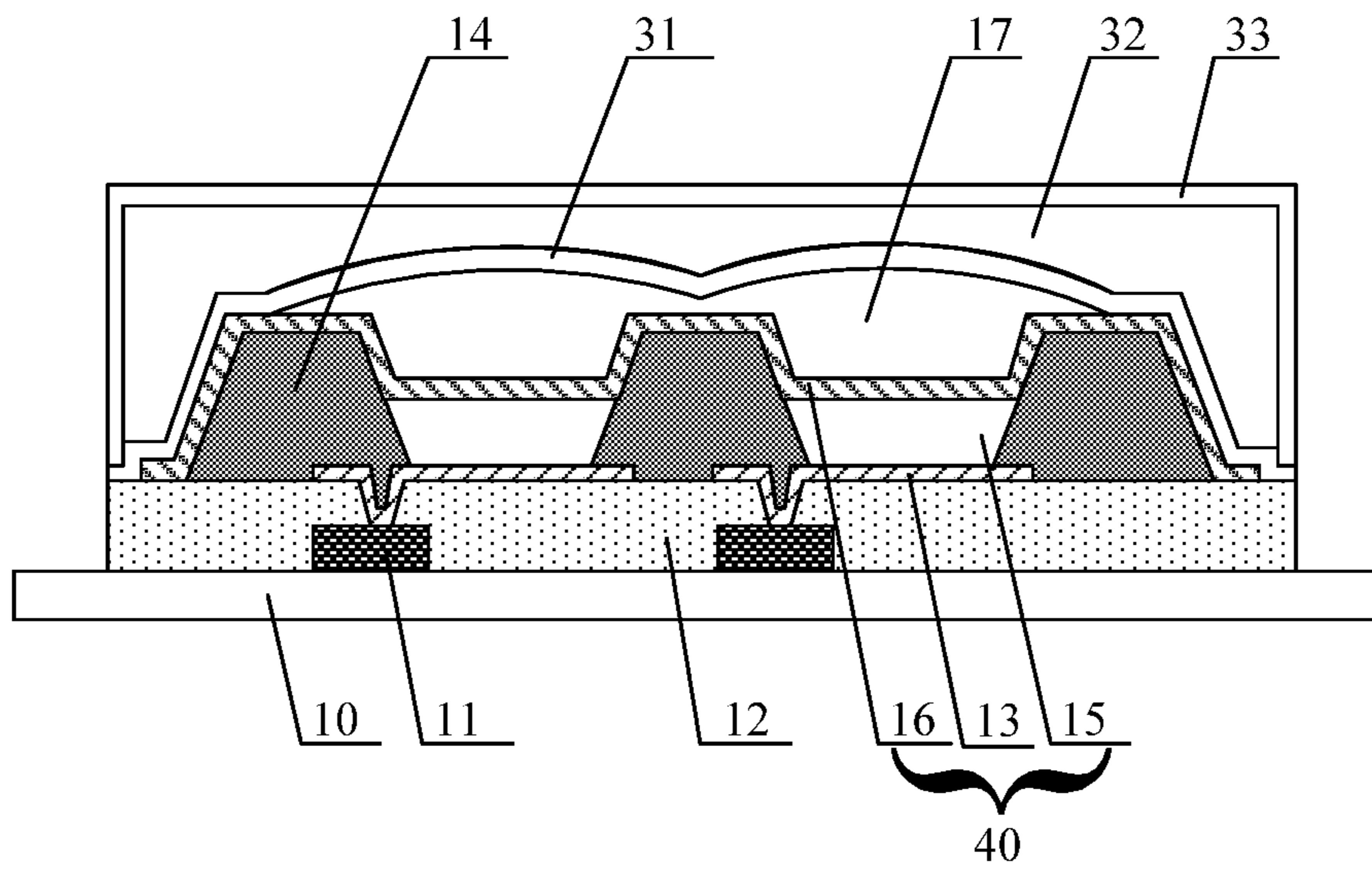


FIG 12



**1****OLED PANEL HAVING AUXILIARY  
CATHODE****CROSS-REFERENCE TO RELATED  
APPLICATIONS**

The application claims priority to the Chinese patent application No. 201710880512.5, filed on Sep. 25, 2017, the entire disclosure of which is incorporated herein by reference as part of the present application.

**TECHNICAL FIELD**

Embodiments of the present disclosure relate to an organic light-emitting diode (OLED) panel and a manufacturing method thereof.

**BACKGROUND**

Organic light emitting diodes (OLEDs) relate to a phenomenon that organic semiconducting materials and luminescent materials are driven to emit light by applied electric fields through actions of carrier injection and recombination. Compared to liquid crystal display (LCD) panels, OLED display panels have advantages such as lower power consumption, faster response speed, wide viewing angle, high contrast ratio, and so on. Especially in the field of flexible display, OLED display panels still have a good display effect in a state of having a certain bending radius, and therefore have a remarkable broad prospect in the field of wearable products.

At present, OLED display panels are divided into two types of structure: top-emitting structure and bottom-emitting structure. Light emitted from a top-emitting type OLED display panel transmits from a side of a cathode, so the cathode of the top-emitting OLED panel needs to use a transparent conductive material such as thin Mg & Ag alloy, indium zinc oxide (IZO), or the like. The transparent conductive cathode may be manufactured through methods such as vacuum evaporation, magnetron sputtering, chemical vapor deposition, or the like.

**SUMMARY**

At least one embodiment of the present disclosure provides an OLED panel, comprising: a substrate; a plurality of OLED devices disposed on the substrate, wherein the OLED devices comprise a cathode and have light emitting areas respectively; and an auxiliary cathode, wherein the auxiliary cathode is disposed on the cathode of the OLED devices in electrical contact with the cathode and the auxiliary cathode is at least partially located in the light emitting areas of the OLED devices, and a material of the auxiliary cathode is a transparent conductive material.

In the OLED panel provided by at least one example, a light emergent surface of the auxiliary cathode protrudes outward along a light emergent direction of the OLED device.

In the OLED panel provided by at least one example, the transparent conductive material of the auxiliary cathode comprises a transparent conductive oxide.

In the OLED panel provided by at least one example, the transparent conductive oxide comprises one or more of indium zinc oxide, indium tin oxide, zinc oxide, and indium oxide.

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In the OLED panel provided by at least one example, portions of the auxiliary cathode on two adjacent OLED devices are connected to each other.

In at least one example, the OLED panel further comprises: a pixel driving circuit disposed on the substrate and an insulating layer covering the pixel driving circuit, wherein the OLED devices are disposed on the insulating layer.

In at least one example, the OLED panel further comprises a thin film encapsulation structure, wherein the thin film encapsulation structure is disposed on the auxiliary cathode and covers the insulating layer.

In the OLED panel provided by at least one example, the thin film encapsulation structure comprises a first inorganic encapsulation layer, and the first inorganic encapsulation layer is disposed on the auxiliary cathode and covers the insulating layer.

In the OLED panel provided by at least one example, the thin film encapsulation structure comprises a first inorganic encapsulation layer, an organic encapsulation layer and a second inorganic encapsulation layer, the first inorganic encapsulation layer is disposed on the auxiliary cathode and covers the insulating layer, the organic encapsulation layer is disposed on the first inorganic encapsulation layer, and the second inorganic encapsulation layer is disposed on the organic encapsulation layer.

In the OLED panel provided by at least one example, a projection of the organic encapsulation layer on the substrate encloses a projection of the cathode of the OLED devices on the substrate, and the projection of the organic encapsulation layer on the substrate is located inside a projection of the first inorganic encapsulation layer on the substrate.

In the OLED panel provided by at least one example, a projection of the second inorganic encapsulation layer on the substrate encloses the projection of the organic encapsulation layer on the substrate.

In at least one example, the OLED panel further comprises an encapsulation substrate and a sealant, wherein the encapsulation substrate is disposed on the side of the OLED panel far away from the substrate, the sealant is disposed at periphery of the insulating layer, and the substrate is connected to the encapsulation substrate through the sealant.

At least one embodiment of the present disclosure also provides a manufacturing method of an OLED panel, comprising: forming a plurality of OLED devices on a substrate, wherein the OLED devices comprise a cathode and have light emitting areas respectively; and forming an auxiliary cathode on the cathode of the OLED devices, wherein the auxiliary cathode is at least partially located in the light emitting areas and is in electrical contact with the cathode, and a material of the auxiliary cathode is a transparent conductive material.

In the manufacturing method provided by at least one example, a light emergent surface of the auxiliary cathode protrudes outward along a light emergent direction of the OLED device.

In the manufacturing method provided by at least one example, forming the of auxiliary cathode on the cathode of the OLED devices comprises: preparing a solution containing the transparent conductive material; printing the solution on the cathode by using an ink jet printing method; and solidifying the printed solution to form the auxiliary cathode.

In the manufacturing method provided by at least one example, an aqueous oxygen content of the solution is about 0.8 ppm to 1.2 ppm.



## BRIEF DESCRIPTION OF THE DRAWINGS

In order to clearly illustrate the technical solution of the embodiments of the disclosure, the drawings of the embodiments will be briefly described in the following. It is obvious that the described drawings are only related to some embodiments of the disclosure and thus are not limitative of the disclosure.

FIG. 1A is a structural schematic view of a top-emitting OLED panel;

FIG. 1B is a schematic top view of the OLED panel as illustrated in FIG. 1A;

FIG. 2 is a structural schematic view of another top-emitting OLED panel;

FIG. 3 is a schematic cross-sectional view of a top-emitting OLED panel provided by a first embodiment of the present disclosure;

FIG. 4 is a schematic top view of the top-emitting OLED panel provided by the first embodiment of the present disclosure;

FIG. 5 is a schematic cross-sectional view of a top-emitting OLED panel provided by a second embodiment of the present disclosure;

FIG. 6 is a schematic cross-sectional view of a top-emitting OLED panel provided by a third embodiment of the present disclosure;

FIG. 7 is a schematic cross-sectional view of a top-emitting OLED panel provided by a fourth embodiment of the present disclosure;

FIG. 8 is a schematic flow chart of a manufacturing method of an OLED panel provided by a fifth embodiment of the present disclosure;

FIG. 9 is a structural schematic view of the OLED panel after forming an insulating layer in the fifth embodiment of the present disclosure;

FIG. 10 is a structural schematic view of the OLED panel after forming OLED devices in the fifth embodiment of the present disclosure;

FIG. 11 is a structural schematic view of the OLED panel after forming an auxiliary cathode in the fifth embodiment of the present disclosure; and

FIG. 12 is a structural schematic view of the OLED panel after forming a thin film encapsulation structure in the fifth embodiment of the present disclosure.

## DETAILED DESCRIPTION

In order to make objects, technical details and advantages of the embodiments of the disclosure apparent, the technical solutions of the embodiments will be described in a clearly and fully understandable way in connection with the drawings related to the embodiments of the disclosure. Apparently, the described embodiments are just a part but not all of the embodiments of the disclosure. Based on the described embodiments herein, those skilled in the art can obtain other embodiment(s), without any inventive work, which should be within the scope of the disclosure.

Unless otherwise defined, all the technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art to which the present disclosure belongs. The terms "first," "second," etc., which are used in the description and the claims of the present application for disclosure, are not intended to indicate any sequence, amount or importance, but distinguish various components. Also, the terms such as "a," "an," etc., are not intended to limit the amount, but indicate the existence of at least one. The terms "comprise," "compris-

ing," "include," "including," etc., are intended to specify that the elements or the objects stated before these terms encompass the elements or the objects and equivalents thereof listed after these terms, but do not preclude the other elements or objects. The phrases "connect," "connected," "coupled", etc., are not intended to define a physical connection or mechanical connection, but may include an electrical connection, directly or indirectly. "On," "under," "right," "left" and the like are only used to indicate relative position relationship, and when the position of the object which is described is changed, the relative position relationship may be changed accordingly.

Although a cathode material used for an OLED is conductive, it still has a certain electric resistance value. Therefore, when the size of an OLED panel reaches 10 inches or more, just the electric resistance of the cathode material of the OLED may cause a significant voltage drop. As a result, the display brightness of the display panel decreases, and the display uniformity of the display panel reduces accordingly.

To cope with this problem, the electric resistance value of the cathode material needs to be reduced. For example, an auxiliary cathode may be provided to reduce the electric resistance value of the cathode as a whole. There are two main methods for forming the auxiliary cathode: an evaporation method and a cell-forming method. However, whether the evaporation method or the cell-forming method is used, the manufactured auxiliary cathode is located on a pixel defining layer. Due to the limitation of the area where the pixel defining layer is located, the area of the auxiliary cathode is greatly limited, so that the electrical conductivity of the cathode fails to completely meet the requirements by final products. When the auxiliary cathode is manufactured by using an evaporation method, a high-precision evaporation mask is needed. However, the metal material cannot be removed by using a cleaning process after it is deposited on the mask, so the mask is scrapped after being used several times, resulting in a higher production cost. When the auxiliary cathode is manufactured by using a cell-forming method, the formed cathode is not compatible with a thin film encapsulation (TFE) formed later, and the water and oxygen barrier property may be achieved only by the sealant located along the edge of a display panel, so that the water and oxygen barrier property of the panel is greatly degraded.

FIG. 1A is a structural schematic view of a top-emitting OLED panel. As illustrated in FIG. 1A, a thin film transistor 11, an insulating layer 12 and an OLED device are sequentially disposed on a base substrate 10. The OLED device comprises an organic light emitting layer 15 defined by a pixel defining layer 14, an anode 13 and, a cathode 16. The anode 13 is located between the organic light emitting layer 15 and the insulating layer 12 and is connected to the corresponding thin film transistor 11. The cathode 16 covers the pixel defining layer 14 and is in contact with the top side of the organic light emitting layer 15. The thin film transistor 11 is connected to the anode 13 to control the voltage applied to the anode 13. The organic light emitting layer 15 emits light by the drive of an electric field generated between the anode 13 and the cathode 16.

In order to improve luminance of the organic light emitting layer 15, the electric resistance of the cathode 16 needs to be reduced so as to improve the electrical conductivity of the cathode 16. In FIG. 1A, an auxiliary cathode 17 is formed on the cathode 16 by using an evaporation method and is connected to the cathode 16. The material of the auxiliary cathode 17 may use a metal such as magnesium (Mg), silver (Ag), aluminum (Al), gold (Au) or the like. Due to the poor light transmittance of the metal materials, the



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auxiliary cathode 17 is usually formed on the pixel defining layer 14, so as to prevent the auxiliary cathode 17 from affecting the light emission of the organic light emitting layer 15 and reducing the aperture ratio of the display panel, which is illustrated in FIG. 1A.

Due to the limitation of an area where the pixel defining layer 14 is located, the area of the auxiliary cathode 17 is greatly limited accordingly, as illustrated in FIG. 1B. FIG. 1B is a schematic top view of the OLED panel as illustrated in FIG. 1A. It can be seen from FIG. 1B that, because the area of the pixel defining layer 14 is small, the area of the auxiliary cathode 17 may also be formed small, i.e., the area of the auxiliary cathode 17 is limited. In FIG. 1B, the auxiliary cathode 17 is of a narrow strip. Although such an auxiliary cathode 17 improves the electrical conductivity of the cathode 16 to a certain extent, it does not allow the electrical conductivity of the cathode to completely meet the requirements. In addition, when the auxiliary cathode 17 is manufactured by using the evaporation method, a high-precision evaporation mask is needed. After the metal material is deposited on the mask, it cannot be removed by using a cleaning process, so the mask is scrapped after being used several times, resulting in a higher production cost of the OLED panel.

FIG. 2 is a structural schematic view of another top-emitting OLED panel. Different from FIG. 1, in FIG. 2, the auxiliary cathode 17 is disposed on an encapsulation substrate 18, and a transparent electrode 19 is deposited on the auxiliary cathode 17. The transparent electrode 19 may use a transparent conductive material such as ITO, IZO or the like. In a packaging process, the transparent electrode 19 on the encapsulation substrate 18 and the cathode 16 are bonded or assembled together by using the cell-forming method, so that the auxiliary cathode 17 is connected to the cathode 16 to reduce the electric resistance of the cathode 16.

It can be seen from FIG. 2 that the substrate 10 is connected to the encapsulation substrate 18 through a sealant 20. The sealant 20 surrounds the thin film transistor 11, the OLED device, the auxiliary cathode 17 and the transparent electrode 19 to achieve the water and oxygen barrier property for the OLED panel. However, the OLED panel in FIG. 2 cannot use a thin film encapsulation, so the water and oxygen barrier property of the OLED panel is greatly degraded.

With respect to the above problem that the electrical conductivity of the cathode of the OLED display panel cannot completely meet the requirements, the embodiments of the present disclosure provide an OLED panel and a manufacturing method thereof.

At least one embodiment of the present disclosure provides an OLED panel. The OLED panel comprises a plurality of OLED devices disposed on a substrate. For example, these OLED devices correspond to a plurality of sub-pixel units, for example, which are arranged in an array on the substrate. The OLED panel also comprises an auxiliary cathode. The auxiliary cathode is disposed on a cathode of the OLED devices in electrical contact with the cathode, and is located in light emitting areas of the OLED devices. A material of the auxiliary cathode is a transparent conductive material, for example, a transparent conductive oxide material.

At least one embodiment of the present disclosure also provides a manufacturing method of an OLED panel, which comprises: forming a plurality of OLED devices on a substrate; and forming an auxiliary cathode on a cathode of the OLED devices, which is disposed on the cathode of the

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OLED devices in electrical contact with the cathode and is at least partially located in light emitting areas of the OLED devices, and a material of which is a transparent conductive material, for example, a transparent conductive oxide material.

In the embodiments of the present disclosure, by disposing the auxiliary cathode in the light emitting areas, because the area of the light emitting areas is large, the area of the auxiliary cathode is enlarged as well, and the electric resistance of the cathode (a power supply terminal) is greatly reduced, thereby reducing the voltage drop caused by the cathode itself, allowing the electrical conductivity of the cathode to meet the requirements of a large-sized display panel, and improving the brightness uniformity of the display panel.

The technical proposal of the embodiments of the present disclosure is described below in detail with reference to the specific examples.

FIG. 3 is a schematic cross-sectional view of a top-emitting OLED panel provided by a first embodiment of the present disclosure. It can be seen from FIG. 3 that the OLED panel comprises a plurality of OLED devices 40 disposed on the substrate 10, and the OLED devices 40 each comprise an organic light emitting layer 15 defined by a pixel defining layer 14, an anode 13 located on the bottom side of the organic light emitting layer 15, and a cathode 16 located on the top side of the organic light emitting layer 15. The OLED panel further comprises an auxiliary cathode 17. The auxiliary cathode 17 is disposed on the cathode 16 of the OLED devices in electrical contact with the cathode 16 and is at least partially located in light emitting areas of the OLED devices 40. The light emitting areas of the OLED devices 40 correspond to the areas where the cathode 16 and the anodes 13 of the OLED devices 40 face each other respectively. In each of the light emitting areas the organic light emitting layer 15 can emit light under the effect of the electric field between the cathode 16 and the anode 13, and the organic light emitting layer 15 located outside these areas do not participate in light emission substantially. The material of the auxiliary cathode 17 is a transparent conductive material, for example, a transparent conductive oxide.

As illustrated in FIG. 3, the OLED panel further comprises a pixel driving circuit including a plurality of thin film transistors 11 and the insulating layer 12 covering the thin film transistors 11 which are disposed on the substrate 10 in sequence. The OLED devices 40 are disposed on the insulating layer 12. The OLED devices 40 correspond to the thin film transistors 11 respectively. For example, each thin film transistor 11 as illustrated in the figure is a driving transistor in the pixel driving circuit which is configured to control a driving electric current for driving one OLED device 40 to emit light under control of an input data signal.

The anode 13 is located between the organic light emitting layer 15 and the insulating layer 12, and for example, is electrically connected to a source electrode or a drain electrode of the corresponding thin film transistor 11 through a via hole formed in the insulating layer 12, so as to receive the driving electric current. The cathode 16 covers the pixel defining layer 14 and is in contact with the top side of the organic light emitting layer 15. The organic light emitting layer 15 emits light by the driving of the electric field between the anode 13 and the cathode 16.

As illustrated in FIG. 3 and FIG. 4, the OLED devices 40 correspond to a plurality of sub-pixel units, for example, which are arranged in an array on the substrate. For example, these sub-pixel units comprise a red sub-pixel unit R, a green sub-pixel unit G, and a blue sub-pixel unit B. Accordingly,



the OLED devices of the red sub-pixel unit R, the green sub-pixel unit G, and the blue sub-pixel unit B respectively use different organic light emitting materials to emit red light, green light, and blue light. The pixel defining layer **14** is formed on the substrate and comprises a plurality of openings **142** defined by convex portions **141**, each opening **142** corresponding to one or more sub-pixel units.

For example, the cathode **16** is a common cathode, i.e., the cathodes (portions of the cathode **16**) of at least two adjacent OLED devices are integrated, and the cathode **16** simultaneously covers at least two adjacent sub-pixel units and the convex portion **141** of the pixel defining layer **14** between the sub-pixel units. Relative to the substrate **10**, the portion of the surface of the cathode **16** in the light emitting area of the OLED device is lower than the portion on the convex portion **141** of the pixel defining layer **14**, thus the cathode **16** has a concave portion in the light emitting area, and the auxiliary cathode **17** is at least partially formed in the concave portion of the cathode **16**, which helps to form the auxiliary cathode **17** by using an ink jet printing method and control the profile of the auxiliary cathode **17**. For example, the auxiliary cathode **17** covers the light emitting areas of the sub-pixel units in a curved profile.

The pixel driving circuit used for the pixel unit may adopt any suitable pixel driving circuit, such as a 2T1C pixel driving circuit, i.e., two thin film transistors (TFTs) and one storage capacitor Cs are used to realize the basic function of driving an OLED to emit light. One of the two TFTs is a driving transistor and the other is a switching transistor. The switching transistor is electrically connected to a gate line and a data line to input a data signal of the data line under control of a scan signal of the gate line to control the driving transistor. A variety of pixel driving circuits having compensation functions based on the basic 2T1C pixel driving circuit are also provided in the industry. The compensation function may be achieved through the way of voltage compensation, electric current compensation, or composite compensation. The pixel driving circuit having a compensation function may be, for example, 4T1C, 4T2C, or the like.

In order to facilitate the light emission of the organic light emitting layer of the OLED devices, a material of the cathode **16** may be a transparent conductive oxide, such as IZO, ITO, or the like. Because the transparent conductive oxide itself has a certain water barrier property, when the cathode **16** is made of the transparent conductive oxide, it is more beneficial to manufacture the auxiliary cathode **17** by using an ink jet printing method and controlling the profile of the auxiliary cathode **17**.

The auxiliary cathode **17** is disposed on the cathode **16** and at least partially located in the light emitting areas of the OLED devices **40**. That is, the orthographic projection of the auxiliary cathode **17** on the substrate **10** may be entirely within the light emitting areas, or may be partially within the light emitting areas. Because the surface area of the light emitting areas of the OLED devices is larger than the surface area of the top surface of the pixel defining layer between the OLED devices, when then auxiliary cathode **17** is formed on the cathode **16**, the surface area of the auxiliary cathode **17** is greatly increased, enabling the combined electrical conductivity of the auxiliary cathode **17** and the cathode **16** to be greatly improved to meet the requirements of a large-sized display panel, and to improve the brightness uniformity of the display panel. It can be seen from FIG. 3 that the auxiliary cathode **17** is disposed on the cathode **16** and stretches across the area where the organic light emitting layer **15** is located, i.e., at least partially covers the light

emitting areas of the OLED devices, for example, completely covers the light emitting areas of the OLED devices.

In at least one example, in order to more effectively reduce the electric resistance of the cathode to improve the electrical conductivity of the cathode, preferably, portions of the auxiliary cathode **17** on two adjacent OLED devices **40** are connected to each other, so that the area of the auxiliary cathode **17** is larger, further improving the electrical conductivity of the cathode **16**. It can be seen from FIG. 3 that portions of the auxiliary cathodes **17** on at least two adjacent OLED devices **40** are connected to each other as one integral body on the pixel defining layer **14** between the two adjacent OLED devices **40**.

FIG. 4 is a schematic top view of the top-emitting OLED panel provided by the first embodiment of the present disclosure. In FIG. 4, the organic light emitting layers (of the pixel units) of the OLED panel is arranged in a form of "Δ", and the portions of the auxiliary cathode corresponding to two adjacent organic light emitting layers in each column are connected to each other, i.e., the auxiliary cathode is longitudinally connected as illustrated. It is easily understood by those skilled in the art that when the organic light emitting layers are arranged in a matrix or other arrangement, the auxiliary cathode may be longitudinally connected or transversely connected according to needs. Of course, the auxiliary cathode may also be connected both longitudinally and transversely. The portions of the auxiliary cathode which are connected to each other can increase the thickness and area of the cathode overall, reduce the electric resistance of the cathode, and improve the electrical conductivity of the cathode.

In order to prevent the auxiliary cathode **17** from affecting the luminous efficacy of the organic light emitting layer **15**, for example, the material of the auxiliary cathode **17** is a transparent conductive oxide such as one or more of indium zinc oxide (IZO), indium tin oxide (ITO), zinc oxide (ZnO), indium oxide (In<sub>2</sub>O<sub>3</sub>) or the like. The auxiliary cathode **17** made of the transparent conductive oxide can not only reduce the electric resistance of the cathode **16** and improve the electrical conductivity of the cathode **16**, but also has preferable photopermeability.

In this embodiment, a light emergent surface of the auxiliary cathode **17** protrudes outward along the light emergent direction (that is, the upward direction in the figure) of the OLED device. For example, the light emergent surface of the auxiliary cathode **17** is a spherical surface which protrudes outward along the light emergent direction, for example, an ellipsoidal surface. When the light emergent surface of the auxiliary cathode **17** protrudes outward along the light emergent direction, the auxiliary cathode **17** has a function of a convex lens, so that the light emitted by the organic light emitting layer **15** can be collected, the luminous efficacy of the light emitting layer of the OLED can be improved, and the brightness of the panel can be increased accordingly. For example, in order to reduce the cost of the display panel, the material for manufacturing the auxiliary cathode may be made into a solution by using a solution process first, and the auxiliary cathode **17** may be manufactured by using an ink jet printing method. By manufacturing the auxiliary cathode **17** using the ink jet printing method and no longer using the evaporation method, it is no longer necessary to use an evaporation mask, which reduces the manufacturing cost of the display panel.

In the embodiment of the present disclosure, the OLED panel further comprises a thin film encapsulation structure. In the embodiment illustrated in FIG. 3, the thin film encapsulation structure is disposed on the auxiliary cathode



17 and covers the insulating layer 12. The thin film encapsulation structure in this embodiment comprises a first inorganic encapsulation layer 31. The first inorganic encapsulation layer 31 is disposed on the auxiliary cathode 17 and covers the insulating layer 12, thereby forming a closed and airtight space between the first inorganic encapsulation layer 31 and the insulating layer 12. The anode 13, the organic light emitting layer 15, the cathode 16, the auxiliary cathode 17, and the pixel defining layer 14 are all located in the closed and airtight space, thereby improving the water and oxygen barrier property of the OLED panel.

FIG. 5 is a schematic cross-sectional view of a top-emitting OLED panel provided by a second embodiment of the present disclosure. Different from the first embodiment, in this embodiment, as illustrated in FIG. 5, the thin film encapsulation structure further comprises an organic encapsulation layer 32 and a second inorganic encapsulation layer 33 sequentially disposed on the first inorganic encapsulation layer 31. A projection of the organic encapsulation layer 32 on the substrate 10 encloses a projection of the cathode 16 on the substrate 10, and the projection of the organic encapsulation layer 32 on the substrate 10 is located inside a projection of the first inorganic encapsulation layer 31 on the substrate. A projection of the second inorganic encapsulation layer 33 on the substrate 10 encloses the projection of the organic encapsulation layer 32 on the substrate 10.

Here, the organic encapsulation layer 32 can provide a flat surface for the panel, so that the flat second inorganic encapsulation layer 33 can be manufactured on the surface of the organic encapsulation layer 32. In order to prevent the organic encapsulation layer 32 from being permeated by aqueous vapour and oxygen, the projection of the organic encapsulation layer 32 on the substrate 10 is located inside the projection of the first inorganic encapsulation layer 31 on the substrate 10, and the projection of the organic encapsulation layer 32 on the substrate 10 is also located inside the projection of the second inorganic encapsulation layer 33 on the substrate 10. With such a structure, the first inorganic encapsulation layer 31 and the second inorganic encapsulation layer 33 can cover the organic encapsulation layer 32 and prevent the organic encapsulation layer 32 from being permeated by aqueous vapour and oxygen.

Such a thin film encapsulation structure further improves the hermeticity of the enclosed space between the thin film encapsulation structure and the insulating layer 12, further improves the water and oxygen barrier property of the OLED panel, and improves the lifetime of the OLED panel.

FIG. 6 is a schematic cross-sectional view of a top-emitting OLED panel provided by a third embodiment of the present disclosure. Different from the first embodiment, in this embodiment, as illustrated in FIG. 6, the OLED panel further comprises the encapsulation substrate 18 and the sealant 20. The encapsulation substrate 18 is disposed on the side of the OLED panel far away from the substrate 10. In FIG. 6, the substrate 10 is on the bottom side of the panel and the encapsulation substrate 18 is on the top side of the panel. The sealant 20 is disposed at the periphery of the insulating layer 12. The substrate 10 is connected to the encapsulation substrate 18 through the sealant 20. In this way, a closed and airtight space between the substrate 10, the encapsulation substrate 18 and the sealant 20 is formed, and the OLED devices and the like are enclosed therein, thereby further improving the water and oxygen barrier property of the OLED panel.

FIG. 7 is a schematic cross-sectional view of a top-emitting OLED panel provided by a fourth embodiment of the present disclosure. Different from the second embodi-

ment, in this embodiment, as illustrated in FIG. 7, the OLED panel further comprises the encapsulation substrate 18 and the sealant 20. The encapsulation substrate 18 is disposed on the side of the OLED panel far away from the substrate 10. The sealant 20 is disposed at the periphery of the insulating layer 12. The substrate 10 is connected to the encapsulation substrate 18 through the sealant 20. In this way, a closed and airtight space between the substrate 10, the encapsulation substrate 18 and the sealant 20 is formed, and the OLED devices and the like are enclosed therein, thereby further improving the water and oxygen barrier property of the OLED panel.

It should be noted that the substrate and the encapsulation substrate in the above embodiments may use a rigid material such as glass or the like, and may also use a flexible material such as polyimide (PI), polyethylene terephthalate (PET) or the like for applying to flexible panels.

At least one embodiment of the present disclosure provides a manufacturing method of an OLED panel. FIG. 8 is a schematic flow chart of a manufacturing method of an OLED panel provided by a fifth embodiment of the present disclosure. The manufacturing method comprises the following operations:

Step S1: forming a plurality of OLED devices on a substrate; and

Step S2: forming an auxiliary cathode on a cathode of the OLED devices, which is at least partially located in the light emitting areas and a material of which is a transparent conductive material.

In one example, a light emergent surface of the auxiliary cathode protrudes outward along a light emergent direction, for example, which has a spherical surface.

In one embodiment, one example of step S2 may comprise: preparing a solution containing the transparent conductive material by using a solution process; printing the solution on the cathode located in the light emitting areas by using an ink jet printing method; and solidifying the printed solution to form the auxiliary cathode which is at least partially located in the light emitting areas.

Because the organic light emitting layer cannot withstand a high temperature, for example, when the solution printed on the cathode of the OLED devices is solidified, the curing temperature is about 70 °C to 90 °C, preferably about 70 °C to 80 °C, so as to prevent the organic light emitting layer from being damaged or degraded.

In order to prevent other materials on the panel being adversely affected by water and oxygen, for example, an aqueous oxygen content of the prepared solution containing the transparent conductive material is about 0.8 ppm to 1.2 ppm, preferably about 0.8 ppm to 1 ppm.

For example, when the ink jet printing method is performed, the sprayed solution of the transparent conductive oxide is at least partially located in the concave portion of the surface of the cathode. The concave portion helps to maintain the solution of the transparent conductive oxide and the profile of the auxiliary cathode formed after being solidified.

The technical proposal of the embodiments of the present disclosure is described in detail with reference to the exemplary manufacturing process of the OLED panel.

First, a plurality of thin film transistors 11 for the pixel driving circuit are formed on the substrate, and then the insulating layer 12 covering the thin film transistors is formed. This process may use the known semiconductor preparation technique and will not be repeated here. In one example, the via hole used for exposing the drain electrode



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of the thin film transistor **11** is disposed in the formed insulating layer **12**, as illustrated in FIG. **9**.

Then, the OLED devices corresponding to the thin film transistors are formed on the insulating layer **12**. One example of forming the OLED device comprises: forming the anode **13** of the OLED device on the insulating layer **12**, and the anode **13** is connected to the drain electrode of the corresponding thin film transistor **11** through the via hole in the insulating layer **12**; on the insulating layer **12** formed with the anode **13**, forming the pixel defining layer **14** for defining the area where the organic light emitting layer is located; forming the organic light emitting layer **15** within the opening defined by the pixel defining layer **14**; and forming the cathode **16** of the OLED device, which covers the pixel defining layer **14** and is in contact with the top side of the organic light emitting layer **15**, as illustrated in FIG. **10**. The material of the anode **13** may be the transparent conductive oxide such as IZO, ITO, or the like. The material of the pixel defining layer **14** may be an inorganic insulating material (for example, a silicon oxide) or an organic insulating material (for example, an organic resin). The material of the cathode **16** may be the transparent conductive oxide such as IZO, ITO, or the like. For example, the thickness of the cathode **16** is about 500 angstroms to 1500 angstroms. In another example, the cathode **16** may also be a composite structure made of the transparent conductive oxide and a metal material.

Further then, the auxiliary cathode is formed on the cathode of the OLED devices by using the ink jet printing method. The auxiliary cathode is at least partially located in the areas where the organic light emitting layers are located (i.e., light emitting areas). The light emergent surface of the auxiliary cathode protrudes outward along the light emergent direction. The material of the auxiliary cathode is the transparent conductive oxide.

One example of forming the auxiliary cathode comprises: preparing the solution containing the transparent conductive material by using the solution process, the aqueous oxygen content of the solution being about 0.8 ppm to 1.2 ppm so as to prevent other layers from being water oxidized by the solution; printing the solution on the cathode **16** located in the light emitting areas by using the ink jet printing method; and solidifying the solution printed on the cathode **16** of the OLED devices, for example, the curing temperature being about 70 °C to 80 °C, so as to form the auxiliary cathode **17**, which is at least partially located in the light emitting areas and the light emergent surface of which protrudes outward along the light emergent direction, as illustrated in FIG. **11**.

The material of the auxiliary cathode **17** is the transparent conductive oxide, such as one or more of IZO, ITO, ZnO, In<sub>2</sub>O<sub>3</sub>, or the like. In the concave portion formed by the cathode **16**, due to the surface tension of the solution, the light emergent surface of the formed auxiliary cathode **17** protrudes outward along the light emergent direction. Such an auxiliary cathode **17** can improve the luminous efficacy of the organic light emitting layer **15**, thereby promoting the display brightness of the display panel.

For example, the portions of the auxiliary cathode **17** located in two adjacent light emitting areas are connected to each other, which is beneficial to reduce the electric resistance of the cathode and to improve the electrical conductivity of the cathode.

In one example, when the auxiliary cathode is formed, the thickness of the auxiliary cathode may be controlled by controlling the number of droplets of the solution. For example, the central thickness of the auxiliary cathode **17** is about 1000 angstroms to 2000 angstroms.

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After that, the thin film encapsulation structure is formed on the auxiliary cathode. One example of forming the thin film encapsulation structure comprises: forming the first inorganic encapsulation layer **31** on the auxiliary cathode **17** which covers the insulating layer **12**; forming the organic encapsulation layer **32** on the first inorganic encapsulation layer **31**, the projection of the organic encapsulation layer **32** on the substrate **10** enclosing the projection of the cathode **16** on the substrate **10**, and the projection of the organic encapsulation layer **32** on the substrate **10** being located inside the projection of the first inorganic encapsulation layer **31** on the substrate **10**; and forming the second inorganic encapsulation layer **33** on the organic encapsulation layer **32**, and the projection of the second inorganic encapsulation layer **33** on the substrate **10** enclosing the projection of the organic encapsulation layer **32** on the substrate **10**, as illustrated in FIG. **12**.

At last, on the substrate **10**, the sealant **20** is coated at the periphery of the insulating layer **12**; and the encapsulation substrate **18** is disposed on the top of the sealant **20**, and the sealant **20** is solidified. The substrate **10** is connected to the encapsulation substrate **18** through the sealant **20**. The closed and airtight space is formed between the substrate **10**, the encapsulation substrate **18** and the sealant **20**, and the OLED devices and the like are enclosed therein, as illustrated in FIG. **7**.

What are described above is related to the illustrative embodiments of the disclosure only and not limitative to the scope of the disclosure; the scopes of the disclosure are defined by the accompanying claims.

What is claimed is:

**1.** An organic light emitting diode (OLED) panel, comprising:

a substrate;

a plurality of OLED devices disposed on the substrate, wherein the OLED devices comprise a cathode and have light emitting areas respectively; and

an auxiliary cathode,

wherein the auxiliary cathode is disposed on the cathode of the OLED devices in electrical contact with the cathode and the auxiliary cathode is at least partially located in the light emitting areas of the OLED devices, a material of the auxiliary cathode is a transparent conductive material, and

a light emergent surface of the auxiliary cathode protrudes outward along a light emergent direction of the OLED device, a protruding portion of the auxiliary cathode completely covers the light emitting areas of the OLED devices, and the light emergent surface is a surface of the protruding portion away from the substrate.

**2.** The OLED panel according to claim **1**, wherein the transparent conductive material of the auxiliary cathode comprises a transparent conductive oxide.

**3.** The OLED panel according to claim **2**, wherein the transparent conductive oxide comprises one or more of indium zinc oxide, indium tin oxide, zinc oxide and indium oxide.

**4.** The OLED panel according to claim **1**, wherein portions of the auxiliary cathode on two adjacent OLED devices are connected to each other.

**5.** The OLED panel according to claim **1**, further comprising: a pixel driving circuit disposed on the substrate and an insulating layer covering the pixel driving circuit, wherein the OLED devices are disposed on the insulating layer.

**6.** The OLED panel according to claim **5**, further comprising a thin film encapsulation structure,



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wherein the thin film encapsulation structure is disposed on the auxiliary cathode and covers the insulating layer.

7. The OLED panel according to claim 6, wherein the thin film encapsulation structure comprises a first inorganic encapsulation layer, and

the first inorganic encapsulation layer is disposed on the auxiliary cathode and covers the insulating layer.

8. The OLED panel according to claim 6, wherein the thin film encapsulation structure comprises a first inorganic encapsulation layer, an organic encapsulation layer and a second inorganic encapsulation layer,

the first inorganic encapsulation layer is disposed on the auxiliary cathode and covers the insulating layer,

the organic encapsulation layer is disposed on the first inorganic encapsulation layer, and

the second inorganic encapsulation layer is disposed on the organic encapsulation layer.

9. The OLED panel according to claim 8, wherein a projection of the organic encapsulation layer on the substrate encloses a projection of the cathode of the OLED devices on the substrate, and

the projection of the organic encapsulation layer on the substrate is located inside a projection of the first inorganic encapsulation layer on the substrate.

10. The OLED panel according to claim 9, wherein a projection of the second inorganic encapsulation layer on the substrate encloses the projection of the organic encapsulation layer on the substrate.

11. The OLED panel according to claim 5, further comprising an encapsulation substrate and a sealant,

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wherein the encapsulation substrate is disposed on the side of the OLED panel far away from the substrate, the sealant is disposed at periphery of the insulating layer, and

the substrate is connected to the encapsulation substrate through the sealant.

12. A manufacturing method of the organic light emitting diode (OLED) panel according to claim 1, comprising:

forming the plurality of OLED devices on the substrate; and

forming the auxiliary cathode on the cathode of the OLED devices.

13. The manufacturing method according to claim 12, wherein forming of the auxiliary cathode on the cathode of the OLED devices comprises:

preparing a solution containing the transparent conductive material;

printing the solution on the cathode by using an ink jet printing method; and

solidifying the printed solution to form the auxiliary cathode.

14. The manufacturing method according to claim 13, wherein an aqueous oxygen content of the solution is about 0.8 ppm to 1.2 ppm.

15. The OLED panel according to claim 1, wherein the light emergent surface of the auxiliary cathode is a spherical surface or an ellipsoidal surface.

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